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New Neutron Time-of-Flight (NTOF)* Facilities at the Brookhaven 200-MeV Linac

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ABSTRACT

The installation of a new beam chopper and radio-frequency quadrupole (RFQ) preinjector (750 keV) at the Brookhaven National Laboratory (BNL) 200-MeV Linac will enable single micropulse selection (pulse width <1 ns) with periods ranging from 400 ns to 10 μs. The standard micropulse intensity is 1.2×10^9 p/μ pulse with dc-average beam currents of 50 nA-1 μA routinely available. The NTOF facilities consists of 30-100 meter flight paths at angles of 0, 12, 30, 45, 90, and 135°. Lower energies of 93, 117, 139, 161, and 181 MeV are also available as well as polarized beams at much reduced intensities. The present paper describes the new facilities, and the capabilities of future improvements and upgrades, for use in the BNL intermediate energy (p,n) experimental program.

Introduction:

A new high current 750 keV RFQ is being installed at the BNL 200-MeV Linac as a replacement for one of the Cockcroft-Walton preinjectors.[1-2-3] A double chopper capable of single micropulse selection at frequencies of 1 Hz up to 2.5 MHz has also been constructed and sucessfully tested with the RFQ. The new double-chopper RFQ system is detailed in the present paper as well as the NTOF capabilities that exist at the 200-MeV Linac complex. Future improvements and upgrades that will be described include a new high intensity polarized ion source, a 400 meter zero degree beam line, a debuncher for reducing the beam spread, and a 0-30° beam swinger on the zero degree line. Experimentally, the facilities will be capable of examining the E_n = 1-200 MeV spectral range without pulsed beam wrap-around and with dc-averaged currents of 50 nA or more.

The Double Chopper RFQ System:

The RFQ Linac input is from a 35 keV H^- magnetron ion source modified to produce an axially-symetric beam matched to the RFQ. The RFQ parameters are summarized in Table 1. Operational tests have routinely produced

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outputs of 50 mA from the RFQ, whereas the current limit is rated at $\geq$100 mA. The RFQ emittance at 50 mA was optimized for transport to the 200-MeV Linac.

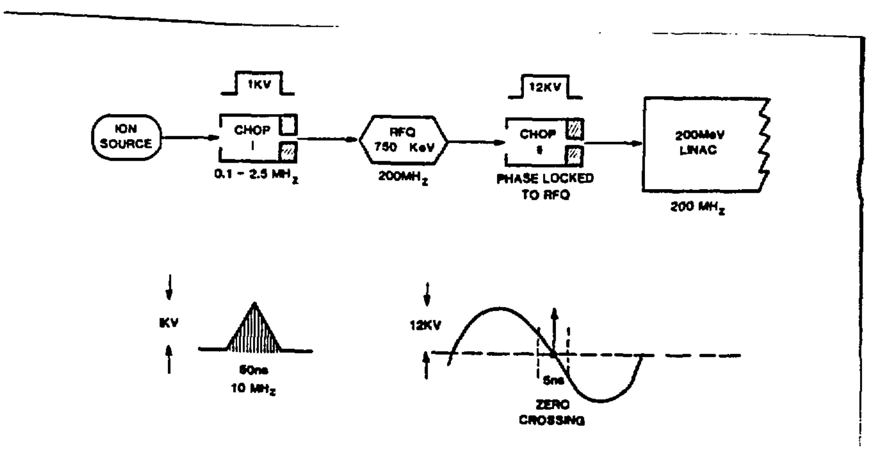
TABLE 1

RFQ Parameters:

Ion	H^+H^-
Input Energy	35 keV
Output Energy	753 keV
Current Limit	$\geq$ 100 mA
Operating Frequency	201.25 MHz
Peak Cavity Power	100 kW
Stored Energy	0.5 Joules
Duty Factor	0.007
Structure	4-vane, ringed
Vane Length	1.62 m

Figure 1 shows an illustration of the double chopper RFQ system. A fast beam chopper (Chop I) located between the ion source and the RFQ can variably bunch-structure the beam with frequencies of 2.5 MHz or less. The first chopper is a slow wave electrostatic deflection device that rejects the beam at a small aperture located before the RFQ. The second chopper (Chop II) is located after the RFQ and is phase locked to the RFQ. Chop II is a fixed frequency sine wave chopper that selects single microbunches (440 ps width) of the 200 MHz RFQ Linac. The duty factor of the double chopper is adjustable from one bunch every 400 ns to one bunch per 450 μs macropulse. The macropulse frequency is 5 Hz. The standard 200 MHz micropulse intensity with 50 mA averaged current is 1.2×10^9 protons/μ-pulse. The dc averaged beam current with 10 μs repetition rate and 5 Hz macrostructure is 50 nA, a value comparable with a 10 μsec 200 MeV pulsed beam from a cyclotron such as the Indiana University Cyclotron.

FIGURE 1: Double Chopper RFQ Showing Single Micropulse Selection

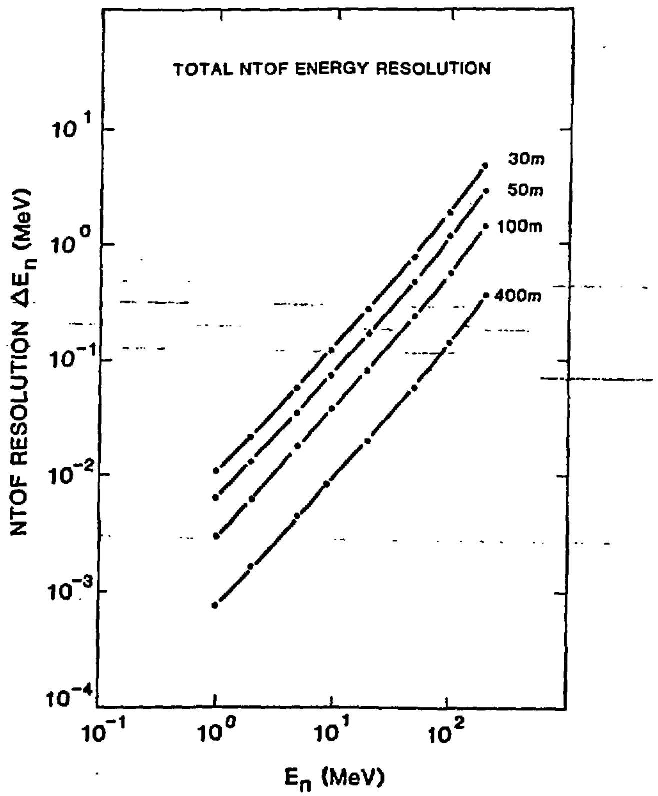


NTOF Facilities and Facilities Performance:

The 200-MeV Linac complex consists of NTOF facilities at the Radiation Effects Facility (REF) and Neutral Beam Test Facility (NBTF). The REF has 30-100 m flight paths at 12, 30, 45, 90, and 135° with approximately 30 m of earth shielding (12" tubes through shielding). The zero degree line located at the NBTF consists of a 10 ft diameter underground tunnel with a present length of 100 meters, a beam dump sweep magnet and a collimation wall (10 ft thick).

The Linac can accelerate proton beams of 92.6, 116.5, 139.0, 160.5, 181.0, and 200.3 MeV with an energy spread of about 140 keV at 200 MeV.[3] The momentum spread in the beam ($\Delta p/p = 7 \times 10^{-4}$), coupled with the 125 m beam transport into the REF and NBTF, widens the width of the micropulse to about 1 ns from the intrinsic width of 440 ps which results from the Linac acceleration. The overall NTOF energy resolution (ΔE_n) that results from a combination of the micropulse width (~1 ns), detector timing resolution (0.8 ns), and the detector width (see Ref. 4 for details) is shown in Figure 2 for various flight-paths and neutron energies. The detector width contributes 58-82% to the uncertainty in the 200-10 MeV neutron energy range respectively.[4-6] The overall resolution is somewhat less than that of other intermediate energy (p,n) facilities but uniquely provides high dc averaged beam currents with repetition rates of 400 ns-10 μs or greater. These low frequency micropulse modes, with 100 kHz and 100 m path lengths, allow the NTOF spectral range of E_n = 1-200 MeV to be acquired without troublesome wrap-around backgrounds. This capability would allow experimenters to look high into the continuum where missing Gamow-Teller (GT) strength may be found.

FIGURE 2: NTOF Energy Resolution as a Function of Neutron Energy and Flight Path



Future Improvements and Upgrades:

A new polarized H^- source is planned to be installed with the double chopper RFQ system after the commissioning and first-year operation of the NTOF facilities. This source will operate at much reduced intensities compared with unpolarized beams but otherwise comparable in intensity to other NTOF facilities at IUCF or LAMPF. Both polarized and unpolarized dc averaged beam intensities can effectively be doubled by increasing the frequency of the macrostructure from the present 5 Hz to the Linac design limit of 10 Hz.

Two improvements to the beam resolution will effectively reduce the 1.4 MeV resolution at 200 MeV (10 μs rep-rate and 100 m path) to less than 350 keV as illustrated in Figure 2. The first is the installation of a debuncher in the transport beam line that will reduce the momentum spread without loss of intensity from the present 950 ns to 700 ns resulting in a increased resolution of about 90 keV. The second improvement is the planned extension of the 100 m zero degree line in the NBTF to 400 m, which results in an overall reduction of 960 keV to the energy uncertainty.

A preliminary design study for a zero degree beam swinger to be installed at the NBTF is currently underway.[7] The beam swinger design calls for a dynamic range of 0-30°, an angular region of much interest in the investigation of GT (p,n) reactions. A one year construction schedule would preclude the use of such a device in the first or second year. The design of a swinger facility is currently being investigated.

Summary:

The installation of a new double-chopper RFQ preinjector at the BNL 200-MeV Linac complex will allow high current NTOF studies at intermediate energies. The NTOF facilities consist of 30-100 meter flight paths at angles of 0, 12, 30, 45, 90, and 135°. Lower energies of 93, 117, 139, 161, and 181 MeV are also available. Future plans call for a 400 m flight path at the zero degree line, a polarized H^- source, and a 0-30° beam swinger to be installed on the zero degree line. This facility uniquely provides single micropulse selection (width <1 ns) with periods of 400 ns to 10 μs or more thereby effectively ensuring no wrap-around background in the E_n = 1-200 MeV spectral range (10 μs period, 100 m flight path).

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Figure Captions:

Figure 1: Double Chopper RFQ illustration showing single micropulse selection.

Figure 2: NTOF energy resolution as a function of neutron energy and flight path.